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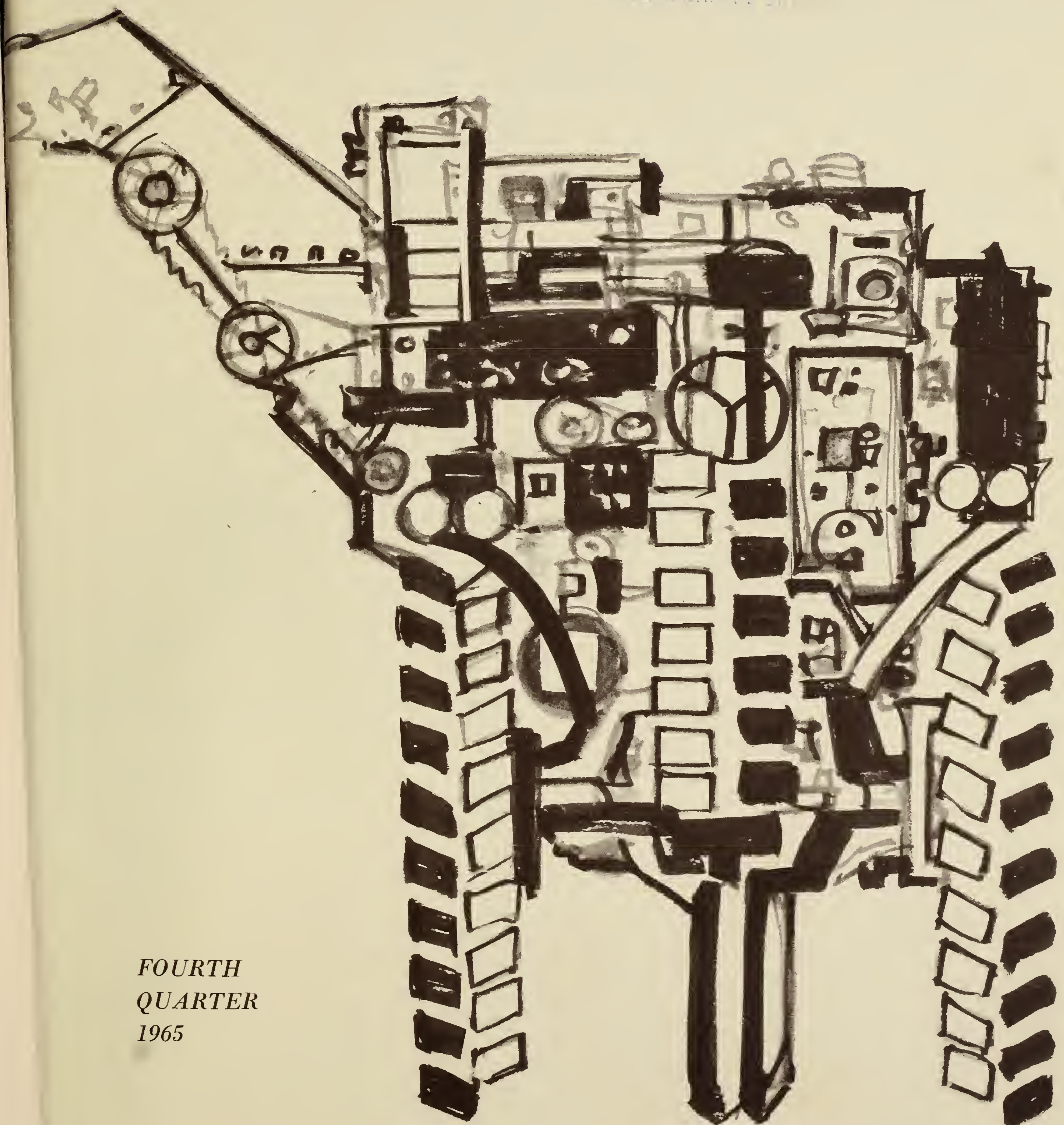

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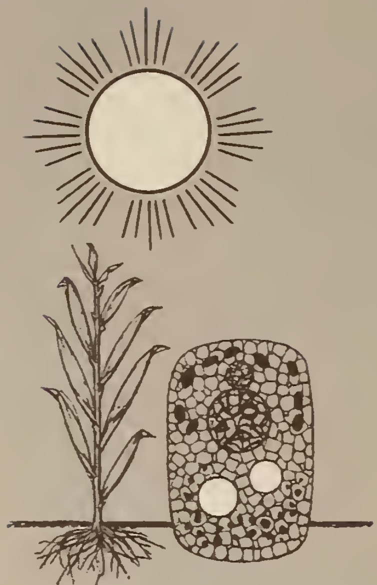
LABOR AND THE ECONOMIC FACTORS IN FRUIT AND VEGETABLE HARVEST MECHANIZATION

Page 1



AGRICULTURAL SCIENCE REVIEW

Fourth Quarter 1965 Vol. 3, No. 4

CONTENTS

True Objectivity

Some years ago an entomologist writing in a British journal made this statement in his methodology section: "I chased my first specimen half a mile before I caught it." His American counterpart undoubtedly would have expressed it this way: "This insect is very elusive and difficult to capture."

It might be argued that both styles have merit, but that point is irrelevant here. Instead the incident is cited because it aptly illustrates a common misconception about objectivity in reporting research.

What is objectivity—true objectivity? Does an author attain it by excluding his personal feelings and reactions? Does he attain it simply by eliminating personal pronouns and relying on the time-honored passive voice and static verbs? Hardly so. True objectivity can never be attained solely by choosing a particular style of writing. Such a device produces nothing more than a veneer of objectivity that serves no useful purpose either for the author or the advancement of scientific knowledge.

Objectvity is actually an attitude of the mind. An author achieves it by schooling himself to view his findings and conclusions through the eyes of a wise critic. He achieves it by placing commonsense and reasoning ahead of bias and provincialism. He recognizes the power of imagination and creativity, yet the wisdom of restraint. He disciplines his mind to become responsive to innovation, quickened by divergent ideas.

Really it is not surprising that most of the stalwarts in the world of science discovered their scientific truths by first learning how to think objectively. Nor is it surprising that their papers, in turn, reflect an aura of true objectivity. Whether their verbs were active or passive was obviously a matter of no consequence to them—and certainly no testimony to the degree of objectivity they achieved.

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Labor and the Economic Factors in Fruit and Vegetable Harvest Mechanization

JOHN W. MAMER AND VARDEN FULLER

THE analysis contained in this paper rests upon a set of propositions dealing with the labor supply situation and prospects. The propositions are, in part, summary of fact, expectations as to what will come to be fact, and inference which we believe may be reasonably drawn from these facts and prospects. Beyond amplifying these propositions and the conclusions we derive from them, we have endeavored to identify and briefly elaborate the tactical approaches that apparently will determine the extent and rate of progress in developing new technology for producing and harvesting fruits and vegetables.

Proposition 1

It Is Highly Improbable That Future Short-Term Seasonal Labor Needs Can Be Met in the Same Way as in the Past

The circumstances and conditions with which present patterns are in accord cannot be relied upon to prevail in the future.

The peaks of labor requirements have become increasingly exposed as they have become shorter in term and as other complementary and supplementary seasonal labor requirements have been reduced and eliminated. They have become more vulnerable as the wage rates and employment standards in agriculture have become increasingly detached from those prevailing in the nonagricultural sectors of the economy.

The availability of workers to meet these needs in the past has depended upon two situations: (*a*) The possibility of integrating several crop activities to get more nearly full-year employment, or (*b*) pockets of poverty, domestic and foreign, containing workers having no full-year work opportunity or other more favorable alternative. The decline of supplementary work has eroded the opportuni-

Adapted from a paper presented at the joint meetings of biological societies sponsored by the American Institute of Biological Sciences, University of Colorado, Aug. 23–28, 1964, and published here as Giannini Foundation Paper No. 264.

ties for pursuing the first alternative; rising standards of welfare, together with the war on poverty, project restraints on the second.

Progress in mechanization of labor-intensive field crops, such as sugar beets and cotton, as well as some progress in mechanization of fruits and vegetables, appears to be making it more difficult for workers to maintain a base of employment by migration or by combining work on several crops in a given labor-market area.

It is conceivable that for years to come foreign workers could be obtained to perform the seasonal hand labor tasks at the wage rates and employment conditions prevailing currently. However, the possibility of continued unemployment of domestic, unskilled workers in local labor markets is likely to militate against foreign farmworker programs. The termination of the Bracero program and the caution exercised in 1965 in authorizing foreign workers under Public Law 414 are two among many manifestations of the unlikelihood of a continued accessibility to such labor supplies.

Proposition 2

Fruit and Vegetable Growers Will Face Higher Wage Rates and Increased Uncertainties Concerning Labor Supply

The general upswing of labor productivity and wages in the economy can be expected to continue. These trends will cast shadows of influence upon the labor costs of all sectors, including those that may not experience rising productivity. The price of the human hand unaided by any source of power to enhance its effectiveness may rise beyond the value of its productivity. Within limits, higher wage rates may be absorbable and they may be helpful in recruiting labor. Nevertheless, it is quite apparent that higher wages, if not accompanied by other changes, have a quite limited role. Increases in wage rates may attract additional workers from among those who do not seek full-year employment, but success in attracting any substantial increase in numbers of such persons is likely to be contingent upon the elimination of much of the primitive technology that characterizes the greater part of the hand work in fruits and vegetables.

The foreign farmworker program makes the availability of seasonal labor a matter of political decision rather than the free play of economic forces in the labor market. Over the years, users of such foreign labor have come to regard the program as necessary and permanent, while the uncertainty of the program increased with each successive extension. But uncertainty cannot be dealt with satisfactorily by continuing to compound it; it needs to be substantially reduced, or better still, eliminated.

Proposition 3

If Seasonality of Employment Cannot Be Sheltered By Complementary Seasonal Employment Within the Area or Along a Planned Migratory Route, Then Alternatives Must Be Chosen

Experimental efforts to expand annual employment of farmworkers by combining the needs of a number of crops have not produced results that indicate that this approach will appreciably change earnings potential.[1] Annual surveys of the earnings of farmworkers do not indicate that those who migrate are successful in building up patterns of migration that are expanding employment.[2]

If seasonal tasks are to be eliminated there are two alternatives: (*a*) Restructure the pattern of crops in a given area to provide more nearly year-around employment, thereby foregoing most of the advantages of specialization that are based on the unique soil and thermal characteristics—factors that provide the basis for high value crops grown in relatively limited areas, or (*b*) produce the crops that provide the most favorable returns based on the climate, soil, and markets, but do so with a technology that does not require seasonal hand labor.

Proposition 4

The Desirable Choice is To Follow the Second Alternative—To Grow the Crops With Technology That Does Not Require Seasonal Hand Labor

Such a choice would permit society to enjoy the benefits of scarce resource endowments and

[1] Dolp, Franz, "Stabilizing Employment of Farm Labor Through Cooperative Organization: A Study of Sequoia Farm Labor Association, Tulare County, Calif." (Unpublished Ph. D. dissertation, School of Business Administration, University of California, Berkeley, 1964.)

[2] See annual issues of *The Hired Farm Working Force*, U.S. Department of Agriculture, Economic Research Service.

specialization of production based thereon. It would remove from fruit and vegetable production the onus of depending upon poverty for its labor supply. Finally, for growers and processors, this is also likely to prove the most profitable alternative.

Proposition 5

The Technology That Can Eliminate or Substantially Reduce Personal Hand Labor Tasks in Fruit and Vegetable Production Can Be Produced

This proposition is a declaration of faith and optimism. However, we do not anticipate that such technology will be forthcoming as an automatic consequence of usual economic incentives.

In the large farm machinery markets, such as those associated with cereals and field crops, the farm equipment industry continues to provide refinements and advances regularly in response to needs and opportunities. Yet the fruit and vegetable industry tends to be bypassed—except for the all-purpose tractor and other general-purpose equipment. Fruit and vegetable producers, with their smaller numbers and heterogenous conditions, have not provided potential markets of sufficient scale to justify very much research and development by private industry.

To assert that fruit and vegetable producers are not likely to receive the necessary attention from the farm equipment and supply industry is to imply only the need of a different mix of private and public effort. If an effective effort to develop new labor technology is to be initiated and sustained, it will be necessary to supplement the limited economic incentives provided by the market.

Further, those instances where impressive progress has been made suggest that we need to revise many of our images of the problem and the appropriate approaches to it. These images refer to the nature of the technology needed, preconceived notions of intermediate and final products, the role of research staffs, and the role of the grower as against processor and marketer. From instances of impressive progress already made or in prospect and from a comprehensive overview of the tasks to be accomplished, we deduce strictures on what to do and what not to do, which we shall call *tactical approaches.*

Tactical Approach 1

A Satisfactory New Technology Need Not Necessarily Require a Direct Substitute for the Human Hand

Economically, efforts to develop a direct mechanical substitute for the human hand are likely to be the wrong approach. Engineers undoubtedly could have made a mechanical hand with appropriate electronic components that would search for ripe tomatoes and gently pick only these from the vine. Such a machine might very well be an electronic marvel—but hardly an economic marvel. It was more economical to remodel the tomato plant and develop a machine that cuts the plant off at the ground and removes the fruit from the vine.

In the lettuce harvest, two experiment stations have produced mechanical substitutes for the human hand—each an electronic-mechanical marvel that selectively cuts firm heads of lettuce. However, the final form of lettuce harvesting technology may be an appropriately developed plant form and a cutting device that removes all heads in a once-over operation. That part of the crop not suitable for packing could be used as animal feed, as in sweet corn where selective harvesting is not economical. This approach would be particularly advantageous if a variety could be developed that would grow to maturity fairly uniformly and remain at roughly that stage for a week or so.

The development of the mechanical tomato harvester and the tomato plant with characteristics that facilitate mechanical harvest is the type of technology that will increasingly come to be substituted for hand labor. The mechanical sugar beet thinner, which substitutes random-stand reduction for the hand methods of selectively thinning beet plants to a uniform pattern is another illustration of new technology that is not a direct substitute for the human hand.

Tactical Approach 2

Every Element of the Production Process From Planting to Consumption May Be Modified in the Effort To Develop the Needed Technology

Given the ultimate demand for food in some form and the constraint that all economic activities need to be profit-earning, all elements in the sequence

from planting to consumption can be variable. No preconceptions need necessarily inhibit the manipulation of planting, cultivating, harvesting, and the final product.

Thus, if advantageous—as with the canning tomato crop—a new plant with dramatically new and important characteristics may be developed to facilitate mechanical harvesting of the crop. Before the canning tomato crop is fully mechanized, it is probable that the characteristics of the fruit and the plant itself will be further modified. And, it is possible that final canned product and product mix may be modified as further work in mechanization research is carried on.

The row-crop apple harvester research at Pennsylvania State University[3] reflects this same flexible approach. Research efforts contemplate a dwarf apple tree trained on trellis wires, with the harvesting mechanism passing over the row like a lumber carrier, shaking the wires to detach the fruit and convey it to a lug box. The asparagus harvest mechanization research which contemplates modification of the final product mix might also be cited as an example of this flexible approach.

The mechanization effort that contemplates no restrictions on the range of items that may be modified is of the most significance to the fruit and vegetable industry and to the members of the economic, biological, and engineering professions. Through this approach, it is possible to utilize a wide range of disciplines available in the universities and in the research facilities of the U.S. Department of Agriculture and also in research facilities of the larger agricultural processing and marketing firms. The full potential of modern scientific disciplines is not likely to be realized if we are compelled to produce a technology in conformity with rigid preconceptions that have no inherent economic relevance.

For economists, efficiency and maximization are cherished concepts. It is in terms of these concepts that we may be able to make our best, and perhaps only, contribution. Maximizing is fine, if done in the right variable. And efficiency is fine, too, unless some important points are overlooked. A harvesting process that delivers 95 percent of the product volume in marketable form will usually be regarded as superior to a process that delivers only 75 percent. Yet, depending on costs and value of byproduct, the latter may be more efficient. If the apparently less efficient method yields higher income to the producer, it is, for the economist, the more efficient method; and since it maximizes the right variable, it also should be the choice of the producer. Yet many of those professionally involved in the process of technological advance will be far removed from the abstractions of the economist as well as the realisms of the producer. Perhaps for them the important thing is to accept an admonition—"beware of your images."

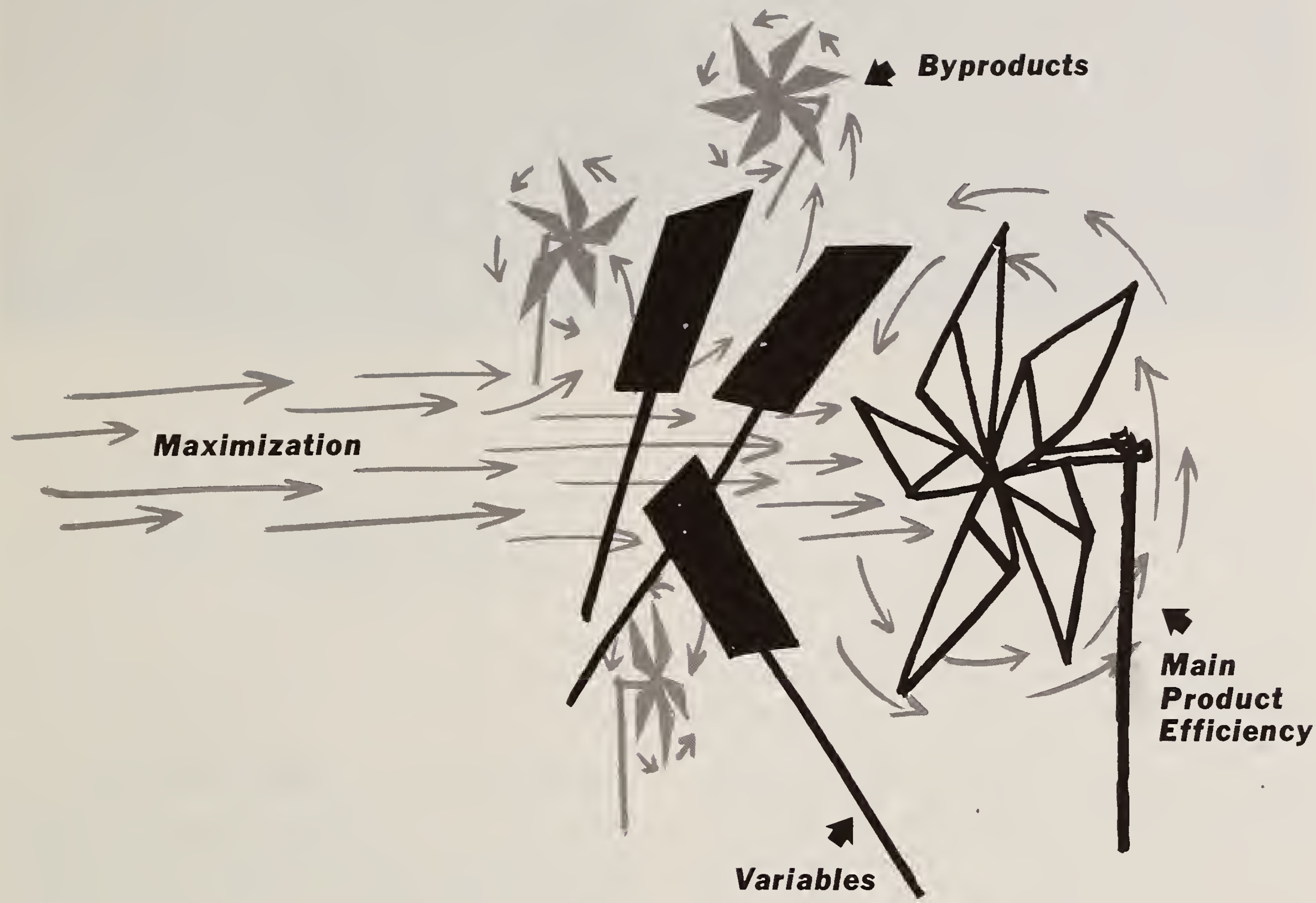
In earlier periods, particularly before World War II, it was common to evaluate new technology by comparing the physical performance of the machine with hand methods. Perhaps one of the most spectacular illustrations of this approach was that followed in the development of the sugar beet harvester. The Great Western Sugar Co. in 1913 first offered to pay $10,000 for a "perfect . . . beet harvester."[4] Some 30 to 35 devices were submitted for testing. Before the offer was withdrawn several years later, 60 to 65 harvesters had been tested; none had qualified. The engineer in charge of the tests expressed the view in 1956 that the standards for evaluating were too high, for some of the machines eventually accepted and commercially manufactured were very similar to those previously rejected. A contemporary account indicated that at least one of the machines worked exceptionally well, but was not satisfactory for the four-row system in Colorado.[5]

Generally a machine was sought that would perform the hand labor of lifting and topping the beets and would operate in all sugar beet areas. Very little or no experimentation had been done to determine to what extent the sugar beet processing facilities would process beets that were imperfectly topped and dirty. The view that to be acceptable the mechanical harvester had to equal the hand

[3] Diener, R. G., Mohensin, N. N., and Jenks, B. L., "Vibration Characteristics of Trellis-Trained Apple Trees With References to Fruit Detachment." (Paper presented at the 1963 winter meeting of the American Society of Agricultural Engineers, Chicago, Dec. 10–13, 1963.)

[4] Musy, Alfred, "The Beet Harvest at Sterling, Colorado," *American Sugar Industry and Sugar Beet Gazette*, 15: 22 December 1913, p. 50.

[5] Mamer, John W., "The Generation and Proliferation of Agricultural Hand Labor-Saving Technology: A Case Study in Sugar Beets" (unpublished Ph. D. dissertation, Department of Agricultural Economics, University of California, Berkeley, 1958) pp. 56–60 and pp. 102–110.



operation securing a well-topped, clean beet prevailed well into the 1940's.[6]

Ultimately, of course, the harvest of sugar beets was mechanized after the wartime labor shortage induced the sugar-processing plants to process mechanically harvested sugar beets that were less than perfectly topped and delivered to the plants with more rocks and soil than was the case when hand harvest prevailed.

The freedom to manipulate all elements from planting to consumption permits the utilization of the widest range of relevant scientific disciplines. It offers a very limited role for the mechanically talented farmer and the mechanical genius. It enlarges the scope of economic analysis. In addition to estimating the economic feasibility of the machine there will now be included such items as an economic evaluation of alternative forms of the final product—a task that may be much more complex and more rewarding.

[6] Mr. J. B. Powers, of the University of California, wrote in 1946 regarding beet harvester mechanization objectives, in part, as follows: "Certain objectives and standards of performance were agreed upon at the outset of the project which was thought to be representative of what the industry might accept as satisfactory performance in a beet harvester. Some were drawn from sugar company recommendations and others from then-current field practices. In light of present practices, some of the objectives appear unreasonably high, but the unsettled state of the beet industry makes revision at this time purely guesswork."

"Progress in Beet Harvest Development at the University of California, 1945," *Proceedings of the American Society of Sugar Beet Technologists, 1946*, p. 502.

Tactical Approach 3

Progress in Fruit and Vegetable Labor Technology Will Depend Upon a Complementary Blend of Public and Private Effort

An illustration of this kind of approach is offered by the beet sugar industry. In 1937, beet sugar processors determined that there was need for new technology to substitute for hand labor in the production of sugar beets, since the changing economic

and social situation was making it uncertain that it would be possible to continue producing by the established hand methods. Further, it was observed that the market for such technology would not provide a compelling incentive to the farm equipment manufacturers to develop, produce, and market new technology. The industry decided to provide additional funds for the agricultural experiment stations to expand the research already underway. Further, the processors provided leadership in facilitating communication among research staffs.

This illustration is important[7] because it shows that a sector of the industry clearly recognized that the market would not support the developmental research, and that the processing sector of the industry could obtain the development of the needed technology by supporting research.

The second adjustment of the mix of public and private effort is the provision for the distribution of educational services. It is to be expected that in mechanizing the production and harvest of fruits and vegetables many innovations will be developed that will require important changes in the character of the plant itself, in the method of growing it, and quite possibly in the form of the final product. Successful use of the new machines may require a substantial educational effort. Licensing arrangements which give exclusive rights to a single manufacturer may encourage the commercial production of an implement but such an arrangement will not take care of the situation that requires that a substantial educational package be distributed with the machine to insure its successful utilization.

An effective performance of the educational function can again be illustrated by the sugar beet industry. Successful use of the mechanical sugar beet thinner requires that growers abandon well-established and long-held concepts of acceptable stands. In addition to underwriting the initial production of these implements, beet processors undertook a comprehensive program to educate growers as to the soundness of the principle upon which the machine is based and its economic merits. Further, many beet processors purchased machines and made these available to the growers on very favorable terms.

It is quite obvious that the stance of the processing or marketing firm is critical. The use of new technology may change the flow of the crop to the processing plant or to shipping facilities, entailing adjustments in receiving. It may, as noted previously, involve modifications in the form of the final product.

If an effective mix of public and private effort is to be achieved, it will be necessary to develop industry leadership—whether by the processing, growing, or marketing sector of the industry—that comprehends the scope of the problem and the possibilities of approaching its solution. Although the agricultural experiment stations and the agricultural extension services may reasonably be expected to contribute to research and educational efforts, there are constraints upon the emergence of all the leadership from these sources. Moreover, experiment station research that contemplates important changes in production procedures, the character of the plant, or the final product is likely to receive a wider and more sympathetic reception if such research is initiated with the support of all sectors of the industry.

[7] The late H. B. Walker commented as follows regarding the sugar beet mechanization project: "The project has been important to the sugar beet industry because of its economic significance. It serves also as an example of research and achievement resulting from coordinated efforts between State and Federal agencies with advisory assistance and financial support from industry."

Walker, H. B., "A Resume of Sixteen Years of Research in Sugar Beet Mechanization," *Agricultural Engineering*, 21: 10, October 1948. p. 425.

FORUM

JOINT APPOINTMENTS IN UNIVERSITIES

THE scientific counterpart of Mr. Chips in his ivy-covered hall is rapidly disappearing from the American scene. We shall all feel remorse at his passing. His ivory tower has been transferred with a wave of granting agency wands into a concrete and stainless steel laboratory where he may be found as frequently as in the classroom.

His students may be hard put to see him. They must arrange for appointments between his sporadic trips to Washington to discuss grant requests or to London to attend an international meeting and his periods of seclusion when he attempts to write reports on research he has in progress. They are also obliged to wait their turn behind an increasingly long line of other graduate students, technicians, and summer help.

The university—or a part of it at least—has gone to explore new horizons. It has taken on an ever-broadening role as a research organization. The demands of our culture have necessitated increasing university participation in world affairs. In no other place is there such a readily accessible concentration of diversified knowledge as on a university campus. The reservoir of knowledge available for research support has a potential for making universities the major innovators of the future.

Under present circumstances, the teacher with a part-time research commitment finds himself handicapped at the starting line in the highly competitive publications race because of lack of time, funds, assistance, and other resources. The fact that his teaching assignments occupy most of his time is frequently overlooked when the annual article count is made. He may even be deposed from the graduate faculty for lack of publication—unable to participate on the committee of students he has a major share in educating. To counter this, he may surreptitiously reduce his teaching allocation and struggle for recognition in the research arena, often with disastrously superficial results.

A teacher frequently is assigned to do research on problems of marginal significance because major problem areas properly receive the attention of his more research-oriented colleagues. He may find himself in a welter of diversified research undertakings because of the necessity for having "someone working on the problem." He must account for this research in spite of the fact that he has insufficient time and support. It is probable that he should receive, in many cases, proportionately greater support in terms of technicians and funds than the full-time researcher, if he is to be productive.

The point is that a realistic evaluation of teaching loads is long past due. In recent years instructional assignments have become more and more time and resource consuming. As a result the research arm of the university is subsidizing a good deal of instruction. What effect could this have on research programs if it continues? Unless the situation is remedied, research will become more superficial as opportunnties to inquire more deeply into challenging new areas become fewer and fewer. It is time to take a closer look at the time spent on teaching commitments by joint appointees.

Joint Appointments and Teaching Personnel

FOR those whose responsibilities are chiefly in instruction, the joint appointment system unquestionably improves opportunties to keep abreast of disciplinary developments. A research interest permits a broadening of contacts with scientists at other institutions, principally through attendance at professional meetings. Unfortunately, classroom assignments and departmental public relations requirements may dictate preferential attendance by research personnel. But teachers should be given

equal opportunity to attend meetings and visit other institutions so that they too might gain some benefit from the system.

Perhaps the thing a teacher finds most difficult to understand is why his instructional commitment cannot be identified and rewarded. A teacher needs a satisfactory method for recognition of his contribution as badly as the researcher needs his teaching time assignment reevaluated. The fact that good instructors are known to their colleagues and students indicates that a rational basis for their recognition exists. Presumably, at least some of the contributory factors could be used as a measure.

Research personnel can make reciprocal contributions by discussing subject matter instruction and departmental curricula. Final curriculum responsibilities, however, should be left to those who have a primary interest in teaching, just as research scientists decide their most promising approaches after suggestions have been offered.

Opportunities to make contacts with students are advantageous to research personnel. Ordinarily an individual on a joint appointment is assigned teaching duties in the subject matter area in which he is doing research. Students benefit from receiving information from an enthusiastic instructor who shows real competence in his subject matter, provided he does not extend his narrow interest in a particular area to cover the entire course at the expense of related information.

Teaching researchers have an excellent opportunity to identify promising students and encourage them to develop greater proficiency by allowing them to assist in research.

However, the research scientist with his assignment in teaching generally finds that, to paraphrase Mark Twain, reports of his responsibilities have been vastly underrated. Teaching takes more time than the hours in the catalogue would indicate. One soon learns that students must be counseled, manuals and laboratory exercises must be developed, intensive study is necessary, course syllabi must be considered, lecture notes readied, examinations prepared and graded, laboratory supplies provided, instructional meetings attended, attendance reports and grades submitted, an occasional parent placated, short course discussions prepared and delivered, and field trips supervised. In the face of all this the research-oriented scientist is likely to rue the day he decided to try his hand

at instruction.

Although research and teaching may be complementary at the university level, an individual scientist may see the two as contradictory entities. The instructor, although he may speculate on future developments, is concerned largely with broad areas of established knowledge, particularly at lower instructional levels. The research scientist is concerned with inquiry into the validity of specific established concepts and the development of new ones. In general, the one tells, the other asks; the one accepts, the other investigates.

A joint appointment results in lost time while the scientist rearranges his thinking each time he converts from one of his occupations to the other. A balanced joint appointment requires alternation of thinking between the poles of teaching and research with the frequency of a syncopated metronome.

Fortunately, these vacillations may be damped by disproportionate time allotments to research and instruction—apparently the more unbalanced the better. In this manner the individual with assignments in both areas can emphasize the one in which he is expected to be most productive. In summary, it appears that a staff should be composed of a continuum of individuals assigned largely or entirely to either instruction or research.

Joint Appointments and Research Personnel

THE joint appointment system draws research and teaching personnel together to their mutual advantage. Locating the research scientist near a library in close association with individuals in his own and related disciplines brings inestimable benefits. Discussions with other members of a large staff frequently result in the development of rewarding new approaches to problems.

Fortunately, the educational function of the university has benefited from association with research. In its most direct form, the relationship between the two may be expressed in terms of end results. The primary product of research effort is research, while the product of resident instruction is the researcher. Interestingly enough, the secondary objectives are reversed so that the graduate student is utilized to develop research results, and conversely research is used to develop the graduate student. Various facets of this anomaly, centering about the relative importance and support which should be accorded each function, have formed the basis for many a late afternoon professional discussion .

An administrative device called a split or joint appointment permits a university scientist to pursue the dual course of academic enlightenment and research achievement simultaneously. In general, this schizophrenic arrangement has worked extremely well. From the administrative standpoint, individual and departmental outlooks have been broadened, programs are better coordinated, rapid program shifts can be made, and personnel and resource utilization have been improved.

If split appointments are used as a matter of course, the basic assumption is that everyone has dual capabilities and interests. The majority do both jobs well. Some, however, are good research scientists but cannot or do not care to teach. Nevertheless, they are obliged to inflict themselves on students by divine right of degree conferral. Conversely, some teachers—perhaps the best ones—are not research inclined. How a necessarily narrow research problem in which they have little interest broadens their teaching is difficult for them to see. It would seem from this that the joint appointment system should not be applied arbitrarily to all university scientists.

On a departmental program basis, the research commitment with its better support and greater public relations potential may prescribe departmental policy. The "junior partner" education function may be subordinated and neglected—in equipment, for example. Its proponents may find themselves making unglamorous "service" student contacts, correcting theses and dissertations more painstakingly than the graduate student chairman, and resenting the "hiring" of graduate students for research ends. The latter sentiment may be well based. A graduate student occupies the place of the indentured servant in the minds and laboratories of many researchers.

This is not to say that the reverse does not also occur. Research personnel may be obliged to develop programs that lend themselves more to student laboratory demonstrations than to problem solution. A careful program balance must be maintained.

Joint appointments necessitate increased participation in administrative functions. Curriculum, construction, policy, and consulting committees require attention. Commitments for foreign assignments must be honored.

The trend toward allocation of funds for research on a short-term grant basis has dictated that the scientists also take on the duties of fund acquisition and—lest his program collapse in midstream—renewal of the grant. In recent years the university scientist has had a more diversified assignment than ever before.

The joint appointment has become a fact of life. Its advantages are numerous; its disadvantages apparent. The latter must be reckoned with in maintaining the high level of research and instructional competence which the universities have demonstrated.

D. R. KING, *Principal Entomologist, Cooperative State Research Service, U.S. Department of Agriculture.*

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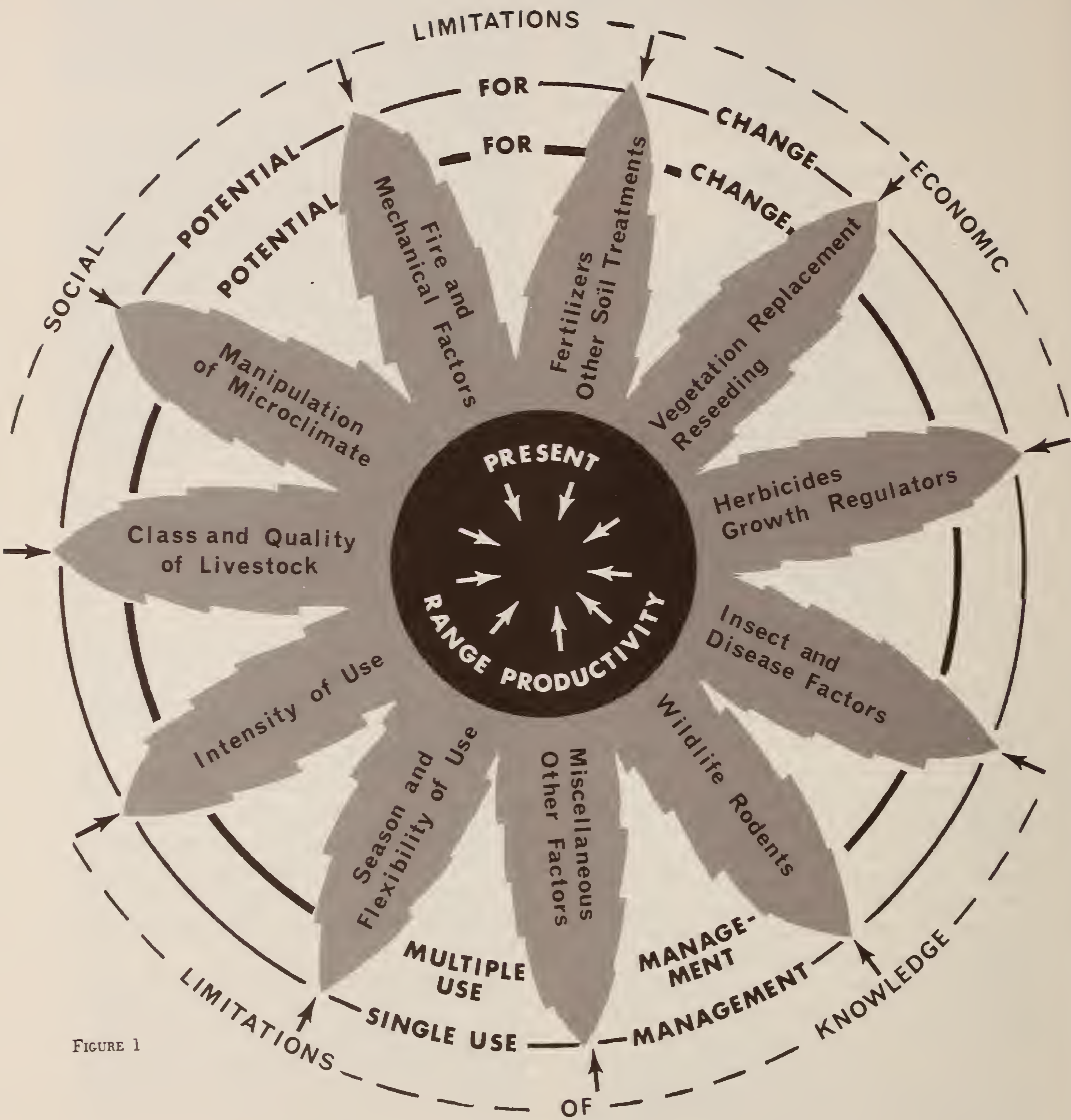


LIMITATIONS
FOR
CHANGE
ECONOMIC
SOCIAL
POTENTIAL
FOR
CHANGE
POTENTIAL
Fire and Mechanical Factors
Fertilizers Other Soil Treatments
Vegetation Replacement Reseeding
Herbicides Growth Regulators
Insect and Disease Factors
Wildlife Rodents
Miscellaneous Other Factors
Season and Flexibility of Use
Intensity of Use
Class and Quality of Livestock
Manipulation of Microclimate
PRESENT RANGE PRODUCTIVITY
MULTIPLE USE
MANAGE-MENT
SINGLE USE
MANAGEMENT
LIMITATIONS
OF
KNOWLEDGE

Figure 1

Gerald W. Thomas and Thomas S. Ronningen

RANGELANDS
-Our Billion Acre Resource

THE United States has over a billion acres of range and pasture land—areas not primarily adapted to crop production or to other intensive land use—areas suitable for grazing by livestock or wildlife.

Substantial limitation of plant growth is often implicit in a concept of rangelands. Lack of sufficient water is the predominant limitation, but rough topography, remoteness, soil adversities, and severe temperatures are also significant restrictions. In the Eastern United States where rainfall is more abundant, grazing areas are frequently classified and managed as permanent pastures rather than native rangelands.

Although our billion-acre grassland resource is tremendous in size, its per-acre income from grazing is small. The total research effort being directed toward its understanding is likewise small, apparently being influenced more by the low per-acre return than by the value of the total resource.

It is not unrealistic to predict that research could lead to techniques for doubling or even tripling the productivity of rangelands. If this is done, the knowledge of many disciplines must be brought to bear on the problem.

Grazing lands present a complicated ecosystem for study—involving the interrelationships among plants, animals, and environment. Basic and applied studies are needed in many fields. But, because of the need for correlating and analyzing the many variables, ecology has become the dominant science to bring the purposes of man in harmony with the forces of nature on range areas. Plant physiology, soil science, climatology, hydrology, genetics, forestry, entomology, taxonomy, wildlife biology, recreation management, and animal science—all are complementary to ecology. And, while the economist is needed for determining managerial alternatives and other economic considerations, the ecologist must provide the essential service for analysis of interrelationships.

A DYNAMIC ECOSYSTEM

ALTHOUGH no single diagrammatic scheme has been devised to adequately portray the many factors in evaluating change and potential productivity of range and pasture lands, figure 1 illustrates the dynamic nature of this problem. No attempt has been made here to "quantify" change. Factors are listed without regard to the intensity of the treatment or the amount of change. For example, on sites where seeding is feasible, this vector may offer the greatest potential for bringing about increased productivity.

Even though vegetation is the basis for this ecosystem design, it is very important to measure present condition and change in terms of the ultimate use to be made of the area. In other words, if livestock production is the major use, then evaluation of change should be made with livestock. Other uses may require a different type of vegetation manipulation and measurement.

There are four major limiting factors to be considered on any range area—economics, social pressures, multiple-use management, and, as previously mentioned, limitations in knowledge.

The prime limitation on improving rangelands is probably an economic one. Most of these areas are normally low in productivity even with improvement, so only inexpensive methods can be justified. Even then, costs must be amortized over relatively long periods. Likewise, there are economic limitations in the conduct of research, particularly in field grazing experiments where large areas of land are needed to provide the necessary replications.

Most range or pastureland is not single-use land. Harvesting the vegetation with livestock is only a part of the total management scheme. The resource may also be important because of water yield and runoff patterns, forest productivity, wildlife, and recreation values.

From a business standpoint, the greatest yield from the resource comes through livestock products with a total income (because of the tremendous acreage) only slightly below that of cultivated crops. It has been estimated that over two-thirds of all feed required by domestic livestock is derived from grasslands.[1] Commercial forests, where also shared for grazing purposes, constitute a sizable income source, and recreation is rapidly becoming of economic importance. But dollar values, even on private ranches, are deceiving. Society has an interest in this land from a multiple-use standpoint, and, in some areas, the social considerations outweigh the direct income alternatives.

A further complicating factor is presented in the ownership pattern of rangelands. Federally owned lands may be assigned a different priority for multiple-use or single-use based on overall public values, whereas private ranchers usually must rely on income from the sale of animals. Betterment of the range for livestock grazing—a single-use—usually will permit greater investment since returns are monetary and come to the rancher. As ways and means are developed to provide additional returns to the rancher for multiple-use, or at least a means of sharing the cost of multiple-use, the potential for change will increase.

[1] Sprague, H. B., "The Importance of Grasslands in Our National Life." *Proceedings:* American Grassland Council, Jan. 29, 1959.

SURVEYS AND EVALUATION

ONE of our major problems is lack of adequate surveys or evaluations of present condition and potential productivity on range and pasturelands. This need is cited in a report prepared jointly by representatives of the major professional agriscience associations. Data on acreage and vegetative makeup of various kinds of rangelands are fragmentary or unreliable.

The action agencies dealing with management or recommendations for the use of public or private grazing lands are proceeding with survey techniques that are often not solidly grounded by research findings. Part of the problem is that range researchers seem to be having difficulty in elucidating survey systems which are both applicable and acceptable over wide areas. Evaluation of present and potential productivity is also a major concern because this survey may determine the future direction of the research effort. On areas suitable for seeding, coupled with complete destruction of existing vegetation, the approach may be primarily agronomically oriented. If, on the other hand, seeding is apparently not feasible the approach may be primarily ecologically oriented and improvement must be achieved through livestock management, use of herbicides, or other practices short of seeding. Many borderline situations also emphasize the importance of accurate surveys.

The traditional approach to vegetation surveys on rangelands (fig. 2) is often described as "dynamic ecology," the central concepts of which are succession and the climax as developed by Cowles, Clements, and Cooper in the early part of this century. However, on ranges where economic return is the dominant criterion, range scientists often equate climax with maximum potential productivity.

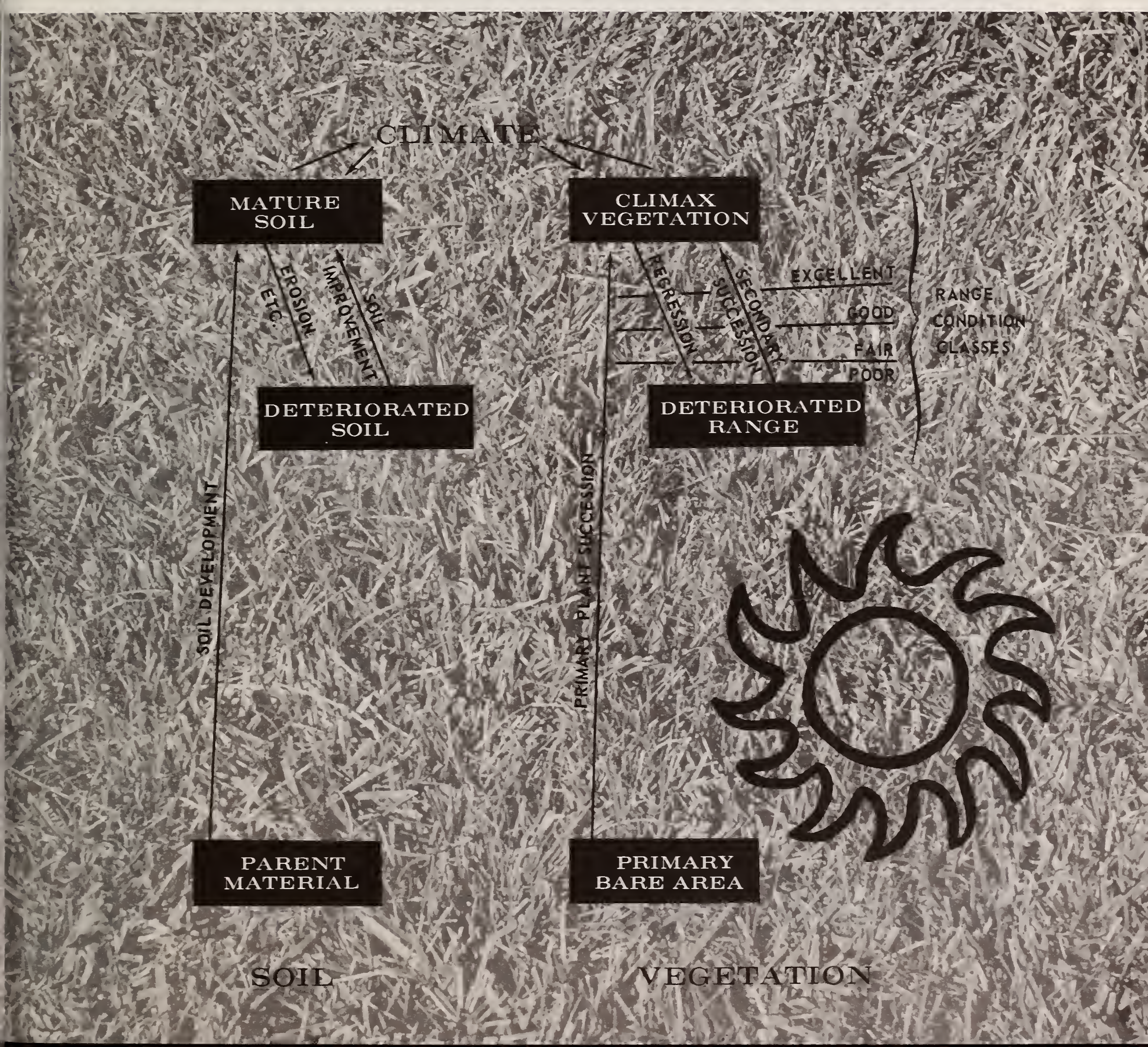
Climate is shown as the overall controlling factor in vegetation and soil development. On any particular area, vegetation changes with time in a rather systematic pattern (primary plant succession) until a plant community (climax) ultimately appears which is in equilibrium with the environment. The concept excludes the influence of man, but includes other natural biotic factors. This climax condition is very dynamic and encompasses normal variation in climate.

Man enters the picture and brings about vegetation change (regression or retrogression), through undesirable manipulation of livestock, harvesting of forests, cultivation, or other disturbance techniques. Man can also bring about improvement by management to hasten "secondary succession." Corresponding changes can take place in the soil, such as deterioration in physical properties or erosion, depending upon the severity of the treatment imposed.

Attempts to quantify the succession-regression patterns were not very successful until the range condition method was developed following World War II. Ecologists first worked with the secondary succession sequence but found this rather frustrating because of the variation in developmental plant communities due to the extent of soil deterioration, availability and nature of seed source, short-run climatic adversity, size of the area, and other factors.

A major contribution was made by Dyksterhuis

Figure 2



and others when a system of range condition classes was proposed based primarily upon the regression sequence using livestock grazing at the disturbance factor.[2] Some Federal action agencies found ready use for this technique in classifying rangelands and interpreting grazing effects.

Under the present range condition system, vegetation classification in space is determined primarily by soil, topographic, and climatic conditions forming "range sites." Once the boundaries of sites are established, the succession-regression patterns (fig. 2) are broken into range condition classes—excellent, good, fair, and poor. These classes, therefore, represent departures from the so-called climax plant community—departures based upon grazing pressure as the disturbance factor. All plants on a particular range site are identified as to their response to grazing and probable place in the climax plant community. Thus, the vegetation survey establishes both present condition, and at the same time indicates potential productivity.

It might be well to digress here to emphasize the importance of reliable soil or site surveys in this system of classification. The spatial pattern of vegetation communities is complex—"a field of phenomena notably lacking in fixed points of reference, lines of division, invariable rules, and easy definitions." [3] The need for accurate soil surveys is just as important on grazing lands as on intensively cultivated cropland. We have been justifiably accused at times of attributing the vegetation differences to poor livestock management. These differences were later found to be associated with variations in microclimate or soils.

While there can be no question as to the overall value of this ecological approach in surveying grazing lands, some important questions remain unanswered. Current discussions among scientists concern proper identification of the climax, what to do about introduced plants, how to evaluate seeded areas, and how to classify certain plants which may respond differently under grazing treatments.

It is generally understood that, because the climax plant community is in equilibrium with the environment, this combination of plants represents the best use of the available soil and water resources—"a partially stabilized community steady-state adapted to maximum utilization of environmental resources in biological productivity." [3] However, if this is true for biological productivity, it is not necessarily true for productivity as measured in terms of man's welfare.

On areas which terminate in a grassland or open savannah climax, evidence does point to a general linear increase in forage productivity as the area develops toward the climax plant community. On the other hand, on sites which support a forest climax, forage production may be greater in one of the lower plant communities. Also, on many areas suitable for seeding, it has been adequately demonstrated that forage productivity is much greater where introduced plants or improved varieties of native species and artificially unbalanced environments are used.

For some of our grazing lands, range condition classification becomes unnecessary and scientists are more concerned with the potential for change rather than with identification of succession-regression patterns. As a matter of fact, in many of the high rainfall areas of Eastern United States, present native vegetation patterns are virtually ignored and the research effort is concentrated on developing improved pastures. This attitude is also typical of much European philosophy where native vegetation has been disturbed to such an extent that succession-regression patterns are difficult to visualize. This does not reduce the need for ecological understanding, but it often shifts the major research emphasis to other scientific disciplines such as plant breeding or agronomy. Despite the variability, relativity, and subjectivity, the concept of climax and systematic vegetation change as influenced by environment has meaning and usefulness for all grazing lands.

LIVESTOCK FACTORS

LIVESTOCK can be both a tool for bringing about vegetation change and a measure of productivity. It therefore becomes necessary to examine livestock production with the dynamics of vegetation in mind. In other words, productivity can be improved by (1) livestock breeding, nutrition and management, and (2) vegetation improvements.

[2] Dyksterhuis, E. J., "Condition and Management of Range Land Based on Quantitative Ecology." *Journal of Range Management*, 2: 3. July 1949.

[3] Whitaker, R. H., "A Consideration of the Climax Theory: The Climax as a Population and a Theory." *Ecol. Monog.* 23: 41–78, 1953.

The interrelationship of livestock to vegetation is the most complicated part of the range ecosystem. Sometimes lower livestock production in the short run is necessary to bring about long-range vegetation improvement. Livestock productivity may also have to be reduced to achieve compatibility with other land uses.

Researchers are continually searching for short-cuts to evaluate forage improvement without comprehensive and costly livestock grazing experiments. As yet, we do not have adequate indicators for predicting livestock performance. Livestock grazing experiments on the range require large areas and many animals for adequate replication and are limited in numbers of experimental variables. Because of the large costs, many experimenters have reduced numbers of animals or replications of treatments with attendant reduction in precision. Development of forage intake and digestibility indicators such as chromogen or chromic oxide, use of esophageal and rumen fistulas, and other methods have aided scientists in assessing animal utilization of range forages. Chemical tests of forage recently summarized by Sullivan,[4] and measurements of plants that serve as indicators of grazing pressures aid in evaluating the range for the animal.

SEEDING

PROBABLY the greatest opportunity for increasing the productivity of many grazing areas is through seeding. The research effort here has been concentrated in the more favorable environments for plant production, although some attempts have been made to establish vegetation on denuded areas under very adverse conditions.

Revegetation research brings into play plant genetics, soil physics and physiology, agricultural engineering, as well as the standard disciplines which deal with culture, management, or animal evaluations. Because of the greater potential offered through revegetation, much of the research effort has been concentrated on this problem. For example, the high level of root reserves maintained by crested wheatgrass clearly explains its excellent tolerance to grazing compared with most native *Agropyrons* which are low in reserves and easily damaged by cattle. At the same time, only a small part of the range area can be improved by seeding with present technology and economic limitations.

[4] Sullivan, J. T., Chemical Composition of Forages. ARS. 34–62. Agricultural Research Service, USDA, July 1964.

Additional research and refinement of methodology will gradually move the economic barriers to revegetation to lands of less and less potential.

MODIFICATION OF MICROCLIMATE

ALL vegetation must be adapted to climate. But the climate which acts on a particular plant community is necessarily the local climate of the site rather than the general climate of the area. Climatic variables may be controlled experimentally by moving a research study to the laboratory; or they may be statistically controlled and studied by properly designed field studies.

The controlled climate laboratory is being used increasingly to uncover basic principles in plant response to temperature, soil moisture, or light factors. This move, although generally considered desirable, is not without certain inherent dangers. Fluctuations in the field or the interplay of factors may themselves have a major influence on productivity.

"Plants in the field grow under conditions which are changing continuously in microclimates which are spatially diverse, and in communities in which individuals may interact with one another. In controlled environments, on the other hand, plants are usually, but not necessarily, grown under conditions which are stable in time, spatially uniform, and free of marked interactions with other individuals." [5] And, as Evans points out: "These are major differences, and ones likely to have profound physiological consequences for plants." When animals, insects, and diseases are added, the situation becomes even more complex in terms of understanding principles.

The opportunity for meaningful modification of microclimate in the field is increasing. Several studies of soil temperature control are presently underway. Various techniques for increasing water concentration and use—range pitting, water spreading, and land modification—are showing promise.

HERBICIDES, FIRE, AND FERTILIZERS

SAMPSON and Schultz [6] estimated a third of a billion acres of rangelands are infested with brush. Poisonous and other undesirable plants infest many more million acres. Woody plants reduce production an estimated 13 percent on western ranges and 20 percent on eastern pastures and ranges.[7]

A number of techniques can be utilized, however, to bring about species composition change or merely to increase productivity of existing vegetation. Research on herbicides has been concentrated on (1) weed control on high value range or pasture, or (2) brush and poisonous plant control on rangelands.

Herbicides, fire, and mechanical methods—singly or in combination—for manipulating plant populations are receiving increased attention. Old

[5] Evans, L., Extrapolation From Controlled Environments in Environmental Control of Plant Growth. Pp. 421–437. Academic Press, New York and London, 1964.

[6] Sampson, A. W. and Schultz, A. M. *In* Unasylva., 10: 1 FAO Rome, 1957.

[7] Losses In Agriculture. Agr. Handbook 291, U.S. Dept. of Agriculture, 1965.

concepts of the "30-inch rainfall" limitation on fertilizers have been radically altered in the past few years, but dryness still limits use of fertilizer on the range. In much of the Great Plains area, on mountain meadows, and on many California annual ranges or where water can be controlled, fertilizers are now considered as a tool for changing plant composition.

WILDLIFE, INSECTS, AND DISEASE FACTORS

MANAGEMENT of native fauna can be an important tool for bringing about vegetation change. However, for certain species of wildlife this is an inadequate consideration because wildlife production—like that of livestock production—can be a positive land use. With the increased demand for hunting and recreation, wildlife may be the most significant source of economic returns from certain areas. Manipulation of vegetation for wildlife purposes may be partially compatible with, or competitive to, livestock grazing and other uses.

An interesting challenge by wildlife biologists has been recently proposed. This concerns the possibility that, on certain areas such as those largely brush-covered, more total animal protein may be produced through certain species of wildlife rather than through domestic animals.

Rabbits and smaller rodents, often utilizing more of the range forage than grazing animals, are receiving considerable research atention. Insects and diseases, except for grasshoppers, have been largely neglected as research problems, partly because their damage is less striking than on cultivated crops, and partly because of the low value of rangelands per unit of area. Entomologists and pathologists too often have not been a part of the forage ecosystem research team. As a result, it might well be that our interpretations of livestock grazing effects are confounded with these and many other factors.

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Frontiers of

Fungus Physiology - Old and New

H. L. BARNETT AND V. G. LILLY

SCIENCE can advance only on the basis of past and present knowledge. The cutting edge of a scientific frontier is that area where questions are being answered, new questions are being asked, and new understanding is being acquired. These new questions constitute the dynamic aspect, the ever-changing frontier arising from the curiosity of the questioner and from the need for solution of practical problems.

No one can say when man first observed fungi and recognized their value as food, or fermenters of fruit juices, or their ability to destroy food and crops. Certainly this was long before the first curious scientists devised means of testing their ideas under controlled conditions. It was about a century and a half ago that scientists began to think in terms of experimenting with fungi as separate organisms. Among these early pioneers the names of Louis Pasteur, Anton De Bary, and Oscar Brefeld are outstanding. Their interest in micro-organisms and curiosity regarding their activities laid the foundation and established the first frontiers in many areas of research that are still being investigated today. The rate at which the frontiers in fungus physiology are being pushed back today depends not only upon the imagination of the investigator, but also upon basic knowledge of fungi, knowledge in related fields, availability and use of modern equipment, and financial support for basic research.

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This brief discussion of frontiers in fungus physiology is intended not so much to summarize facts regarding recent discoveries as it is to call attention to some of the principal areas where outstanding discoveries have been made and to point out some of the many frontiers which promise to challenge many a young mycologist in the future. A detailed summary of recent research on the fungus cell has been published (*1*)[1]

NUTRITION OF FUNGI

MUCH of the credit for developing the pure culture technique for studying fungi belongs to Oscar Brefeld. Early mycologists sterilized the substrate material on which a fungus grew in nature and used it as a culture medium in the laboratory. Many of these natural media were very satisfactory for studying fungus morphology and certain effects of environment. Because the composition of natural media is largely unknown, little can be learned about the nutritional requirements of a fungus unless a synthetic medium of known composition is used. The advantages and disadvantages of natural media have been discussed (*15, 16*).

Pasteur and Raulin, his student, developed the first synthetic medium a century ago for the growth

[1] Italic numbers in parentheses refer to "Literature Cited" p. 24.

of a yeast and for *Aspergillus niger.* This was an important landmark in the study of nutrition of fungi, for this medium was satisfactory for growth of many additional fungi. Although Raulin's medium contained unsuspected contaminating elements, it did permit the recognition of the major nutritional requirements of many fungi.

Microelements

DEMONSTRATION of the requirements for certain metallic elements (manganese, copper, molybdenum) was not accomplished easily because great care was needed to remove these elements from the basal medium. In fact, the concentrations of these elements required by various fungi are still in doubt. Recently it was found that several fungi require unusually high concentrations of manganese for normal growth or sporulation (*20,* and unpublished this laboratory). These elements are essential constituents of specific enzymes, thus explaining the low requirements for them, but it is not clear why some fungi require much higher concentrations than others. Microelement nutrition in fungi has been discussed in a recent review (*19*).

Vitamins

The use of synthetic media made possible the discovery that some fungi require an exogenous source of vitamins, often the same as that required by animals. This discovery ushered in the golden age of vitamins. *Phycomyces blakesleeanus,* the first filamentous fungus shown to require exogenous thiamine (B_1), was used for a time for the bioassay of this vitamin in natural materials.

Only in recent years has it been shown that filamentous fungi require higher concentrations of vitamins for reproduction than for vegetative growth and that the amount required is related to the concentrations of other nutrients, particularly carbon. One typical example is *Sordaria fimicola,* which produces sparse mycelium in media with only a trace of biotin. A slight increase in biotin concentration permits formation of many perithecia, most of which may be empty or contain aborted asci or ascospores. A greater increase in biotin is required for normal ascospore production (*3*). The thiamine-deficient fungus, *Ceratocystis fimbriata,* requires a greater concentration of this vitamin for perithecial formation when the glucose concentration is high than when it is low.

Knowledge of vitamin requirements has made it possible to investigate other nutritional requirements with greater accuracy and may even be used to supplement morphological characters in taxonomy. It has been suggested that the requirement for the intact molecule of thiamine by all tested species of *Phytophthora* may be used to distinguish them from species of *Pythium,* which (with only one exception) are autotrophic for thiamine or require the addition of only the pyrimidine moiety of the vitamin. The possible use of physiological characteristics as aids in distinguishing between specific taxonomic groups should receive more attention.

Carbon Sources

THE utilization of different carbon sources by fungi has long been a subject of study. The first synthetic medium suggested by Raulin contained 70 g of sucrose per liter. Since it is now known that a number of fungi do not utilize sucrose as a sole source of carbon, it is now more common to add glucose to the media used for routine culture of fungi.

Two phases of carbon utilization have largely been ignored—the utilization of mixed carbon sources, such as the effects of one sugar on the utilization of others, and the effects of carbon concentration on growth, sporulation, and other activities. The favorable effect of a small amount of a well-utilized sugar on utilization of a poor carbon source has been pointed out but not explained. Filter-sterilized sucrose is not utilized by *Sordaria fimicola,* but when a small amount of glucose is added the resulting growth is greater than can be accounted for by the glucose alone, indicating utilization of some of the sucrose under these conditions (*17*). A number of similar examples are known.

Another problem that needs clarification is that of sorbose utilization and sorbose inhibition. Some fungi utilize sorbose readily, others apparently do not utilize it, and in a third group it is inhibitory even in the presence of well utilized sugar. For example, *Rhizoctonia solani* grows well on either glucose or maltose, but does not utilize sorbose. It makes only slight growth on a mixture of sorbose and maltose, but this inhibition by sorbose is largely overcome with the addition of glucose. The degree of inhibition increases with a rise in temperature. These results raise many questions that need further investigation.

Insufficient attention has been given to the initial carbon concentration in the medium. Although the concentration is changing constantly as growth occurs, the time and amount of sporulation of a fungus may often be controlled accurately by adjusting the initial concentration of carbon and its ratio to other components of the medium.

In nature, fungi have survived because they have found suitable nutrition and environment in their specific habitats. How well have we been able to duplicate these conditions in the laboratory where most of our research is done? How accurate is our measure of rate of growth of a fungus? This latter question was brought to our attention recently when the growth of *Hypoxylon punctulatum* on agar was compared with that through dead oak sapwood. On an agar medium routinely used for the culture of many fungi, growth was slow and even. The addition of a relatively high amount of manganese induced the formation of rapidly growing, ropy strands of mycelium. Under laboratory conditions this fungus grew longitudinally through autoclaved blocks of oak sapwood at the rate of nearly 1 inch per day. However, the rate increased greatly when the fungus was introduced into standing, dead, girdled red oak trees (*8*). The secret of the more rapid growth must lie in the conditions furnished by its natural habitat. The obvious conclusion is that the fungus physiologist knows very little about the precise conditions affecting growth of fungi in nature.

Work within the last 3 years has revealed that several sterols related to cholesterol induce the formation of oospores by some species of *Pythium* and *Phytophthora* in a synthetic medium (*11*). Several papers have now appeared on this subject. It now seems likely that a sterol was the sporulating factor isolated from peas some 30 years ago that stimulate oospore formation in *Pythium* and *Phytophthora* (*14*). In the light of these recent discoveries, the role of lipid compounds in the nutrition of fungi has not received the attention it deserves.

ENVIRONMENT

Temperature

It seems reasonable to assume that some of the earliest studies on temperature were related to the effects of low temperature on the preservation of food. Probably no factor affecting the fungi has been studied more than temperature, and from the great mass of information certain principles have emerged. Perhaps the most important of these is the recognition that the optimum range for one activity, such as growth, is not necessarily the same as that for another activity, sporulation or production of a specific metabolic product (*16*).

Yet, many questions relating to temperature remain unanswered and await further careful study. If growth or other activity ceases at the maximum temperature because of inactivation of an enzyme system, is the same enzyme affected in all fungi? What unusual enzyme systems are possessed by the thermophilic fungi which are adapted to an optimum temperature range of 40°–50° C., well above the maximum for most fungi?

Light

Few factors affecting the fungi are more interesting and less understood than light. We owe much of our early knowledge to Buller (*6*), who observed many fungi both in nature and in the laboratory and showed that light was not only necessary for the development of reproductive stages of some fungi (*Coprinus, Pilobolus*) but it often aided in the discharge of spores into the air at an angle resulting in maximum dispersal.

Many problems have plagued the investigator of light and fungi. The occasional reports of the favorable effects of light on vegetative growth may be questioned unless adequate precautions have been taken to hold the temperature constant.

A few fungi (*Choanephora cucurbitarum, Sporodinia grandis,* and *Pilobolus* spp.) appear to constitute a group which require alternating light and darkness for production of asexual spores. Sporulation of *Alternaria solani* is inhibited by blue light and recently it has been suggested that this fungus may possess phytochrome, a light-accepting pigment in higher plants (*18*).

Favorable effects of light on production of sporangia and inhibitory effects on oospore production in the same species of *Phytophthora* have been firmly established by recent work at West Virginia University. A relationship between light and nutrition has also been proposed. *Dendrophoma obscurans,* cause of strawberry leaf blight, requires light for sporulation on a synthetic medium, but in

darkness it sporulates well on autoclaved strawberry leaves.

The harmful effects of long exposure of living cells to sunlight have long been recognized and the lethal effects of ultraviolet rays are well known. Favorable effects of ultraviolet light in inducing sporulation of some fungi have been shown (*13*). Production of carotenoid pigments is frequently favored by light. For example, cells of *Dacryopinax spathularia* grown in light contain much more B-carotene than do cells grown in darkness. When cells of this fungus were exposed to visible light of high intensity, there was an inverse relationship between the degree of killing and the amount of yellow pigment (*9*). The conclusion is that the carotene tends to prevent lethal photo-oxidation. These and many other problems lie on the frontier of research on the biological activities governed by light. Since most biologists are poor physicists, cooperation between scientists in these two fields would be highly desirable.

METABOLIC BYPRODUCTS OF FUNGI

ONE of the most productive frontiers of biological research in the last quarter century has been the rapid development and use of antibiotics, both as products of micro-organisms and as chemicals against harmful micro-organisms. The need is sufficiently great to justify continued search for antibiotics which may be used safely and effectively against mycotic and other infections of man. The high degree of success attained with the use of griseofulvin, the treatment against dermatophytes, has given encouragement to these efforts. Calvacin, an extract from *Calvatia* sp., inhibits several kinds of tumors in laboratory animals (*4*).

Much publicity has been given in recent years to the halucinogenic drugs produced by certain fungi. The possible use of these drugs in research on mental health has been proposed, but it has become evident that their use must be restricted to competent researchers who are aware of the dangers which may lie in their misuse.

The poisonous properties of some species of mushrooms have been known since early history and this subject has received much attention in texts and reference books in mycology. Another group of fungi, the "molds," have suddenly been recognized as producers of mycotoxins in food and feed products. A recent book discusses this subject (*24*).

PARASITISM AND PATHOGENICITY

THE basic principles underlying the ability of a fungus to obtain its nutrients from the living cells of another plant and to cause plant disease has been the subject of much research. But the details of many kinds of host-parasite relationships for the most part have not been clarified. De Bary recognized several kinds of relationships between micro-organisms and their hosts and much of the present thinking is based upon his classification of parasites. The new frontier lies in learning how the biotrophic parasites obtain nutrients from the living host cell and how the different parasites bring about the events that result in disease of the host plant. This area of research is increasing in scope and intensity with the increased interest of plant pathologists well trained in biochemistry.

Much of the early work on the pectolytic enzymes as related to plant disease was done by Brown (*5*) and his associates using decays of fruits and vegetables. Today, most of the interest has shifted to a study of the different pectolytic enzymes and their role in vascular wilts of plants.

The "obligate parasites" have remained a challenging group of fungi because they appear to require living host tissue for growth and development. Most of the attempts at culturing these fungi in the laboratory have required the use of complex natural material as a medium, often with the addition of host tissue or host extracts. These attempts, in general, have been disappointing. However, a few years ago a unique approach to the axenic culture of rusts was used with some success (*7*). In these studies, gall tissue of *Juniperus virginiana* infected with *Gymnosporangium* was cultured on synthetic medium. After a few months the rust mycelium in a few cultures became adapted to growth on the medium alone and could be maintained in axenic culture. These cultures retained their ability to infect host tissue. This is interpreted as adaption in a few of the rust cells.

Another new approach to the problems of nutrition of parasitic fungi has been undertaken at West Virginia University, where research has been underway for 10 years using fungi parasitic on other fungi (mycoparasites) to elucidate the basic principles of parasitism (*2*). The use of mycoparasites has the advantages of saving time and space over the usual parasite-green plant combinations.

The necrotrophic mycoparasites, which kill the host tissue and utilize the nutrients, can be cultured easily on synthetic media and are not known to have any special nutritional requirements for their parasitic activities. A number of these parasites are highly destructive to other fungi under laboratory conditions, but relatively little is known about their activities against the organisms in nature. *Trichoderma viride* is the best known and most abundant mycoparasite in nature; its destructive action was described more than 30 years ago. Additional destructive mycoparasites are known in the genera *Penicillium, Rhizoctonia, Cephalosporium, Fusarium, Gliocladium* and others. Recently several wood-rotting basidiomycetes which destroy spores and mycelium of certain other fungi have been added to this list. Hosts include some species which are among the earliest to colonize cut surfaces of stumps and logs. It has been suggested that the ability to destroy these fungi and utilize the organic substances from the cells may aid the basidiomycetes in colonizing the wood. The succession of fungi in wood and other substrates has received too little attention.

The biotrophic parasites, which absorb nutrients from living host cells, often appear to have special nutritional requirements. A water-soluble nutrient from host fungi (or from certain others) is known to be required for axenic growth of two biotrophic mycoparasites, *Calcarisporium parasiticum* and *Gonatobotrys simplex.* The active nutrient appears to be a vitamin-like compound and is effective in extremely low concentrations. It is tentatively called mycotrophein (*23*). But the presence of this nutrient in a fungus does not mean that it is a host, for the host range of the two parasites are entirely different and the nutrient has been extracted from nonhost species. What, then, is the basis of parasitism?

The degree of susceptibility of a plant to attack by parasitic fungi is known to be influenced by the nutrition of the host. Well-fertilized wheat plants are known to be more susceptible to rust than those grown on poor soil. The same relationship appears to occur between certain host fungi and their biotrophic mycoparasites. For example, susceptibility to *Piptocephalis* spp. is directly related to the amount of soluble nitrogen in the host cells, which in turn is related to the concentration of nitrogen and carbon in the medium on which the host is grown. Some other mycoparasites, such as *Gonatobotryum fuseum,* appear to be favored by conditions which favor production of lipids by the host.

The electron microscope has revealed new information about the structure of haustoria of fungus parasites of higher plants and differences have been observed. As these studies continue to probe into the structure of the host-parasite relationships, there is an increasing need for parallel biochemical and physiological studies which may reveal the chemical nature of the changes that occur within the host cell and the physiological activities at the host-parasite interface. Characterization and explanation of the many different host-parasite relationships are among the many problems that are now on the edge of the frontier where plant pathology, fungus physiology, and biochemistry meet.

FUNGI AS FOOD

WITH the rapid increase in world population one of the greatest challenges of man is to find means to keep hunger and malnutrition to the lowest level possible. Stakman (*21*) stated that: "Catastrophic shortages occur periodically for about 40 percent of the world's people, and 60 percent probably are hungry or poorly nourished most of the time." It has been suggested that the food yeasts (*Torulopsis utilis*) may be put to good use (*10*). These yeasts grow rapidly and can utilize the carbon in many waste products containing sugars and starch. With added inorganic nitrogen sources, it is said that this yeast can convert waste products into cell protein faster than any other plant or animal. Approximately 45–50 percent of the yeast cell is protein, 2–6 percent is fat, and it contains all of the known B vitamins. The food yeasts can be grown under factory conditions and the dried product may be added as supplements to food for humans or animals. The unusual synthetic capabilities of these yeasts may offer much hope for a "well-fed future." The use of fungi in the preparation of fermented foods has been reviewed recently (*12*).

CONTROL OF FUNGI

THE loss of nearly 23 percent of the potential agricultural production by diseases, insect pests, and

weeds is more than can be justified (*21, 22*). Present efforts to control plant pathogens by means of chemicals must be supplemented by other means. The use of biological agents has often seemed promising but seldom has proved practical. Certainly this is a frontier which deserves much attention. The fungus physiologist of the future may contribute much to these efforts.

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Weather and Technology

A Critical Analysis of Their Importance to Corn Yields

Robert F. Dale

The following text is based upon a paper given by Dr. Dale at a national conference on "Weather and Our Food Supply" held at Iowa State University May 3–4, 1964, to discuss the reasons for the rapid increase in yield of grain crops in the United States since the mid-1950's. This increase has led to use of the term, "explosion in technology," and a growing tendency to believe that technology has so reduced the influence of weather on grain production that we no longer need fear grain shortages due to unfavorable weather. Dr. Dale describes a method for isolating the effects on corn yields caused by technology and weather, and shows that technology can only be fully effective with favorable weather.

There have been many and continuing attempts to evaluate the effect of weather on crop yields. The qualitative dependency of crop growth and development upon the weather is universally accepted, but the complex plant-environment-technology interactions have usually defeated attempts to qualify this dependence for any but superficial uses of weather information in agricultural planning.

Yield data reflect the composite effect of all environmental, biological, and technological factors upon the growth and development of the crop. The technological factors include changes in residual soil fertility, fertilizer applications, hybrid varieties, crop densities, mechanization, and even supplemental irrigation. The biological factors include insect and disease populations which might themselves be affected favorably by the same environmental conditions favorable to growth of the host crop. The environmental factors include solar radiation, soil moisture and temperature, air temperature and humidity, and rainfall.

All factors influencing crop yields can be more simply identified on small experimental plots than in large areas, such as counties, states, or regions, even though the averaging process over the larger areas tends to reduce yield variance and net composite yield effect of all factors not considered in a crop-environment-technology study. Working with experimental plot data also avoids the need for considering the economic situation or farm programs as another technological factor in production areas. Finally, because of the differences in weather over an area, the environmental average cannot be considered to be any more than an index. With the same rainfall, bottomlands and even shallow depressions within fairly level fields will have more soil moisture—and possibly even temporary water tables—than the better drained soils, especially those on the more droughty south and west facing slopes.

To infer from a study utilizing area average corn yields and precipitation that "so many inches of rainfall will result in so many bushels of corn" is

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only a little more reasonable than claiming that a man standing with one foot in boiling water and the other in ice-water is comfortable with his feet at an average water temperature of 50° C. Although empirical studies based on area average yields and weather variables are useful for quick approximations and answers not otherwise available, it is difficult to visualize and correctly evaluate the results from such studies.

Factors Affecting Corn Yields

THE work of Dale and Shaw (*1*) (*2*),[1] summarized briefly here, was initiated to help interpret agricultural research results, which are conditioned by the weather regime under which the research was performed. Usually, it has been assumed that by replicating the experiment over a number of years and at selected field stations, the environmental effects will average out, leaving the average experimental result representative of the general area or soil unit. Unfortunately, average weather seldom occurs, and the average experimental results are the integrated response to a wide range of conditions.

Experimental plot corn yields from a corn-corn-oats-meadow rotation on well-drained soils at Ames, Iowa and weather data from the same site were

[1] Italic numbers in parentheses refer to Literature Cited, p. 30.

used to study the weather and technological effects on corn yields during 1933–62. The corn yield potential on the experimental plots was considered controlled by five general factors: (1) weather, (2) soil fertility and physical conditions, (3) genetic differences between varieties, (4) stand or geometry of planting, and (5) miscellaneous biological or isolated environmental occurrences. To evaluate the yield effect from any one of these five factors, the effects from the other four have to be considered.

The soil fertility and physical condition factor was held relatively constant by using only second-year corn yields within the same fertility treatments on Nicollet and Clarion soils. Only one fertility treatment is discussed here: plot 01 on which 8 tons of manure were applied once every four years in the fall on meadow before plowing for first-year corn.

Genetic differences between varieties were considered by adjusting all corn yields to an equivalent of those for Iowa 4570—the variety grown from 1957 to 1962 (*2*). Stand was considered as one of the variables in a multiple regression equation. Prior to 1953, the stands on plot 01 averaged 7,400 stalks per acre and since 1953, about 14,700.

Little can be done to consider the miscellaneous biological and isolated environmental effects—weed infestations, insect or disease outbreaks, severe wind and hailstorms, freezes—until the first four effects are evaluated. This fifth factor was not considered and contributes to the variance about the regression yield estimates.

Consideration of weather involves both selection of the weather variables and the period of their integration. For most meaningful environmental-yield relations, the environmental conditions should be studied within the period in which they most directly affect the growth and development of the crop. The more exactly this sensitive period can be determined, the more narrow is the period of pertinent weather measurements and the better is the estimate of weather effects upon the corn crop. The period 6 weeks before corn silking to 3 weeks after silking was selected as the most environmentally sensitive in Iowa. Silking dates were not recorded for the experimental plots, but average State silking dates were available to locate the phenological calendar each year.

To encourage and simplify the use of weather data in interpreting experimental results—usually based on a relatively small number of years of weather-yield data—efforts were aimed toward finding a single weather variable, or derived variable, to insure adequate freedom for analyzing treatment effects. Selection and use of a single environmental variable implies other weather variables either are not limiting yields in the area or that their effects upon yield are inherently included in the selected variable.

Weather Identified by the Moisture-Stress Concept

SEVERAL workers, Philip (*8*), Gardner (*6*), Tanner (*10*), Holmes and Robertson (*7*), Denmead and Shaw (*3*), Eagleman and Decker (*5*), have shown that the loss of soil moisture is a joint function of the atmospheric energy, which causes evaporation from the soil and plant surfaces, and the soil moisture available to supply this atmospheric demand. Denmead and Shaw (*3*) experimentally expressed the amount of soil moisture in the corn root zone at the estimated corn turgor loss point (θ_{TL}) as a function of the transpiration at field capacity. This function is shown as the solid line in figure 1; the abscissa is converted to inches of evapotranspiration at field capacity (ET_{FC}) in 24 hours. The soil moisture ordinate was scaled to percent of available field capacity in the corn root zone; that is, 0 is the 15-atmosphere or estimated permanent wilting point, and 100 percent is field capacity. Dale and Shaw (*2*) identified any day on which the ET_{FC} and available soil moisture (θ) combination fell below the $\theta_{TL}=f(ET_{FC})$ curve as a moisture stress day for corn ($\theta<\theta_{TL}$). A day with ET_{FC} and θ combination falling on or above the curve was identified as a nonstress day ($\theta \geqq \theta_{TL}$). For example, if the ET_{FC} were 0.25 inch in 24 hours, the soil moisture in the corn root zone on that day would have to be at least 85 percent available field capacity to avoid moisture stress in corn and to have been identified as a nonstress day (NSD).

At least 60 percent of the moisture extraction was from the top foot. Therefore, if the percent available field capacity in the top foot was greater than the average for the entire corn root zone, this greater estimate of the available soil moisture was used in the identification of NSD. The $\theta_{TL}=f(ET_{FC})$ curve, experimentally obtained on Colo silty clay loam, was modified by using soil moisture tension curves for Colo and Nicollet soils to more closely approximate the moisture stress situation on the

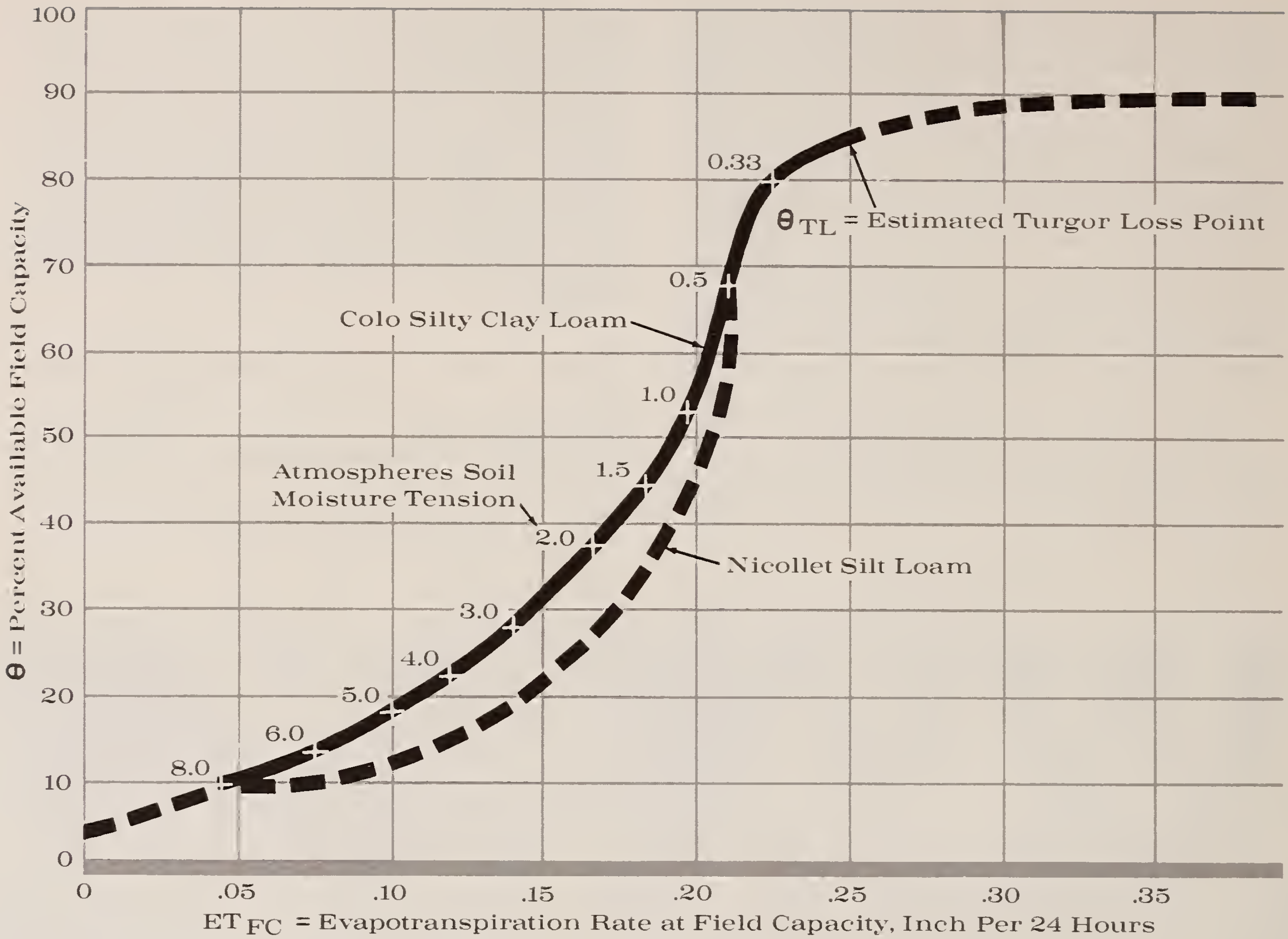


FIGURE 1. Soil moisture in the corn root zone, or the top foot, at the estimated corn turgor less point (θ_{TL}) as a function of the evapotranspiration at field capacity. Solid curve from Denmead and Shaw (*3*) and dashed curve modified by Dale and Shaw (*2*) to Nicollet soil.

Clarion and Nicollet experimental plots. The modified curve for Nicollet is shown as a dashed line in figure 1. Since cell turgidity is necessary for growth, it was assumed that there would be little or no growth on a moisture stress day and that corn yields should be directly proportional to the number of NSD in the 63-day phenological period, 6 weeks before to 3 weeks after silking.

The two estimates needed to identify a day as one with moisture stress or no stress were the moisture supply (θ), both in the corn root zone and the top foot, and the minimum soil moisture (θ_{TL}) needed to prevent moisture stress in corn, as determined by the ET_{FC} and the functional relation of figure 1. Soil moisture was estimated after the method of Shaw (*9*). The ET_{FC} was estimated from the Weather Bureau class A evaporation pan observations and a corn ET_{FC} evaporation pan relation from Denmead and Shaw (*4*).

Moisture Stress, Stand, and Corn Yields

A MULTIPLE regression model, using the variables year, NSD, NSD², stand, stand², and NSD × stand, was associated with 83 percent of the variance in the plot 01 equivalent Iowa 4570 corn yields. The partial regression coefficient for year (trend) was −1.3 bushels per acre per year, an estimated measure of the average residual fertility decrease from 1933 to 1962. Although this estimate is only as good as the selection of the other variables in the equation, some such technique of considering the environmental and technological factors is necessary to evaluate any residual soil fertility change.

Stand was the only technological variable explicitly defined in the regression. When there were 30 or fewer NSD in the 63-day season, moisture stress was the major factor in controlling corn yields.

There was a steep linear increase in yields with number of NSD, regardless of stand level (*2*). Above 30 NSD, stand was of increasing importance, but moisture stress still seemed to limit yields from higher stands (above 12,000 plants per acre) up to about 40 NSD. Above 40 NSD, stand was of major importance, and the benefits of favorable weather were not fully realized unless stand levels were relatively high.

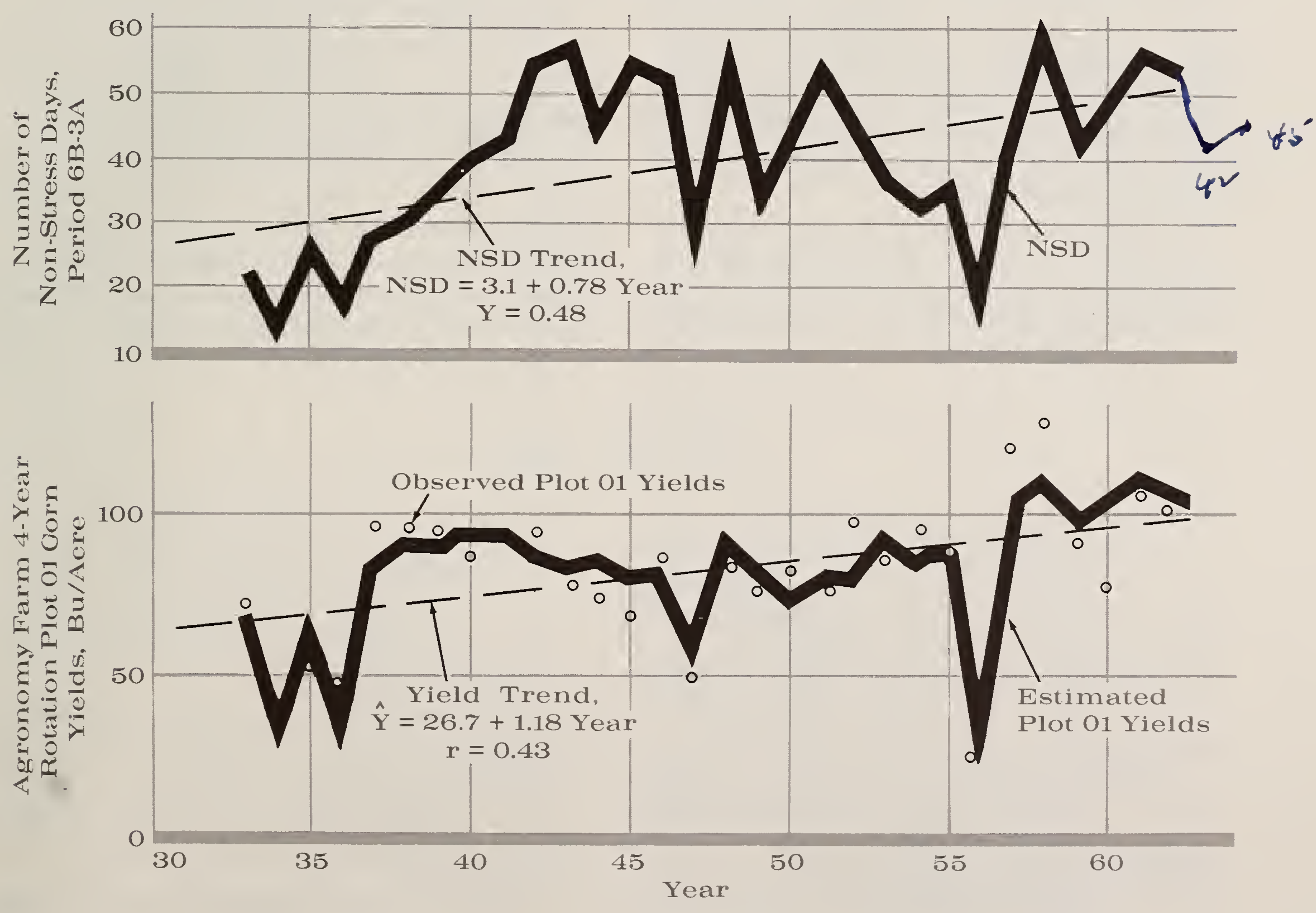
Probability of Non-Moisture Stress Conditions

IF we assume that the weather record of the past 30 years provides the best estimate of the weather regime over the next few years and the number of NSD is a random variable, the probability of having 30 or less NSD in the 63-day phenological period on a Nicollet soil holding 9 inches of available water at field capacity at Ames, Iowa was estimated at about 28 percent (*1*). The chance of having a season with 40 or fewer NSD is about 50 percent. Moisture stress conditions on well-drained soils would appear to limit corn yields at Ames under the plot 01 fertility and stand levels (since 1953) in about half of the years.

The actual (equivalent Iowa 4570) plot 01 corn yields and the regression estimates are shown chronologically from 1933 to 1962 as the lower chart in figure 2. The yield trend is upward and is due to the resultant effect of increase in stands, residual fertility decrease, *and* the weather. It is primarily the low yields in the 1930's and the high yields since 1957 which provide the upward trend.

In the top chart of figure 2, the number of NSD

FIGURE 2.—Lower solid line is estimated corn yields for plot 01, Ames, Iowa for each year, 1933–62; open circles are the observed plot 01 equivalent Iowa 4570 corn yields; dashed line is linear yield trend. Upper solid line is the number of nonstress days for corn in the 63-day period, 6 weeks before to 3 weeks after silking for each year at Ames, Iowa on Nicollet soil holding 9 inches of available water at field capacity; dashed line is linear NSD trend.



is shown for each year. The linear regression trends have been fitted only to show the similarity in trend of number of NSD to that of corn yields in this 30-year period. The trend lines are *not* intended to suggest that corn yields and the number of NSD may be expected to continue to increase at the trend rate. In fact, the 20 years from 1937 through 1956 probably would have shown little, or perhaps a downward trend, in both yields and number of NSD. Both charts show that the estimate of trend depends upon the period analyzed. The number of NSD is considered a random variable; that is, with the true trend as a horizontal line at the mean of 40 NSD. The weather in the 40's—as measured by the NSD variable—was very favorable for corn, but the stand levels on plot 01 were not sufficiently high to realize the full benefit of this weather. There were more than 40 NSD each season from 1941 through 1946, six consecutive favorable years. There were more than 40 NSD each season from 1957 to 1962, with an estimated 42 NSD in 1963 and 45 in 1964 for 8 consecutive years.

Lack of moisture stress conditions allowed the greater stands on plot 01 to have their maximum effect the last 8 years. The probability of having another year with more than 40 NSD is still 50–50, but it is equally likely that there will be 40 or fewer NSD which would not allow the greater plot 01 stand levels to be fully effective.

Variability in the amount, timing and location of precipitation over the State makes it extremely hazardous to use moisture stress computations for corn on well-drained soils at only one location, Ames, for comparisons with State average corn yields for Iowa. A multiple regression of Ames NSD, NSD^2, and year, however, was associated with 74 percent of the variance in the average State corn yields from 1933 to 1962. Since Ames is approximately in the center of Iowa and because the 63-day period of summation tends to smooth the variability of local day-to-day precipitation amounts, this relation may hold on the average. In individual years, however, the relation could be subject to large errors when the accumulation of rainfall at Ames from random spring and summer convective showers chanced to be disproportionately more or less than that received in the principal corn-growing areas of the State. Using the Ames NSD index, the estimate of average trend for all technology in the State was 0.72 bushels per acre per year, which compares favorably to Thompson's (*11*) estimated Iowa corn yield increase due to technology of 0.70 with average weather. A total of more than 40 NSD (at Ames) also appeared necessary to realize the full benefits from the increase in technology on a State basis.

Undoubtedly, it has been stand on plot 01—and overall technology in the State—which has produced the steep upward trend in yields the last few years. But this increase due to stand (technology) was possible only because of the above 40 NSD weather enjoyed at Ames the last 8 years. This favorable weather cannot be expected to continue indefinitely, anymore than one would expect on tossing a coin to continue throwing heads merely because a run of eight heads has occurred.

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LETTERS

MEASURING RESEARCH BENEFITS

IN their article, "Contributions of Agricultural Productivity to National Economic Growth" (*Review,* Vol. 3, No. 2, 1965) Tweeten and Hines measure the benefits from agricultural research and education, reasoning as follows:

1. Research discoveries have substantially increased agricultural production per man.
2. This increased output per man has reduced the manpower needs in agriculture.
3. In consequence, many people have moved from agriculture to industrial jobs where the average value of their output is about twice that in agriculture.
4. Thus, the value of agricultural research can be measured by the increase in national output arising because some farmers—as a result of research findings—left agriculture for industrial jobs and by so doing appreciably increased the real value of their output.
5. Using this approach the authors conclude that each $1 spent on agricultural research and education has yielded about $2 in return.

Reasoning on this grand scale, and treading as it does in places on mushy information, is bound to precipitate controversy among economists and others. Nevertheless, I believe this approach has considerable validity and would be generally accepted by economists. In fact it is essentially an application of thinking formulated by some of the principal patron saints of economics such as Alfred Marshall, and more recently reflected in such USDA publications as "Agriculture and Economic Growth," (AER No. 28).

There probably is less argument with respect to the specific numbers Tweeten uses in applying this approach, although he may well have achieved about as much accuracy as we can expect at present. In using his conclusions, however, there are numerous qualifications which might be important in particular situations. I have singled out the following three for brief comment.

1. *Future may not be the same as the past.* As farm population declines the number of people who could be released from agriculture to go to industrial jobs also declines. Thus, future research and education in agriculture might contribute less to national output than in the past.

2. *Have research and education been the overriding reasons enabling people to move from agriculture to industry?* This concerns what is probably the weakest part of the Tweeten article.

The author defines research and educational expenditures very broadly including, for example, expenditures under the price-support program. There would be value in trying to distinguish between research and education (narrowly defined) on the one hand, and specific measures to encourage the adoption of research findings on the other. Consider the following examples: (*a*) A farm credit program enabling farmers to buy better equipment sooner, (*b*) specific measures to aid farm people to move to industrial jobs, (*c*) a successful diplomatic effort under GATT opening foreign markets for our farm products, or (*d*) broadening of legislation such as crop insurance to reduce risks and encourage adoption of newer methods. All these actions would need to be given some credit along with research and education for increases in the

Adapted from a statement originally prepared for a departmental discussion of the Tweeten-Hines article.

real value of national output.

It might be argued that we already have plenty of unemployed people on farms . . . or that we don't need to find ways by which more farm manpower can be released for industrial jobs. In the short run this may be true, but over a period of several years or longer it is not. If all research in agriculture, for example, were stopped, the number of farm people who would move to off-farm jobs over the next 10–20 years would be smaller than if research continues.

3. *Are Tweeten's conclusions an endorsement for all agricultural research and education?* No. Even the most avid advocates of more research would admit that the foregoing is not a carte blanche endorsement of any and every increase in research and education proposed. It may be very difficult, if not well-nigh impossible, to select at their inception those research or educational projects which will yield most fruitful conclusions. Nevertheless, it also seems evident that there can be worthwhile winnowing. Tweeten refers to one of the most complicated problems in this area: How do the prospective gains from research and education in agriculture compare with those in other parts of the national economy? That is, what priority should agricultural research have in comparison with that relating to health, space, and national defense? The Tweeten approach (and that of economics generally) starts to crumble when applied to such a question simply because of the different end products. Agricultural research produces a greater national output; defense research produces more security. Clearly such questions call for more research about research.

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